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Request for grant of a patent

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1.	Your reference	609GB — 5 NOV 2003
2.	Patent application number *(The Patent Office will fill in this part)*	0325803.5
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	Renishaw plc New Mills Wotton-under-Edge Gloucestershire, GL12 8JR
	Patents ADP number *(if you know it)*	2691002
	If the applicant is a corporate body, give the country/state of its incorporation	United Kingdom
4.	Title of the invention	Method Of Scanning
5.	Name of your agent *(if you have one)*	M J Fowler et al
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	Renishaw plc, Patent Department New Mills Wotton-under-Edge Gloucestershire GL12 8JR
	Patents ADP number *(if you know it)*	

		Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	–		–

		Number of earlier application	Date of filing *(day / month / year)*
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	–	–

8.	Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if: a) any applicant named in part 3 is not an inventor, or b) there is an inventor who is not named as an applicant, or c) any named applicant is a corporate body. See note (d))*	Yes

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Description	7
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Priority documents	0
Translations of priority documents	0
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	0
Request for preliminary examination and search *(Patents Form 9/77)*	0
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Any other documents *(please specify)*	0

11. I/We request the grant of a patent on the basis of this application.

Signature MJarker Date 05.11.2003

AGENT FOR THE APPLICANT

12. Name and daytime telephone number of person to contact in the United Kingdom A Iles 01453 524524

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METHOD OF SCANNING

This invention relates to a method of scanning.

When a rotatable sample holder is used in conjunction with a relatively movable scanning device, it is known to scan around the holder in order to establish or confirm the radius of the holder and the co-ordinates of the origin of the holder. This information is used to interpret data produced by scanning an object located on the sample holder.

A problem with this method is that it assumes that the sample holder surfaces are square and that the circumferential surface of the sample holder remains co-linear with respect to its rotational axis along its length i.e. that the surface of the sample holder on which a sample is located is perpendicular to the rotational axis. Additionally, in order for this assumption to be treated as valid, the equipment must be manufactured to tight tolerances which increases the cost of the equipment.

Accordingly, the invention provides a method of scanning comprising the steps of:

providing a scanning system having a sample holder which rotates about a rotational axis and a relatively movable scanning device;

establishing orientation of the sample holder with respect to the rotational axis;

scanning an object located on the sample holder; and

correcting data from the scan using the orientation of the sample holder.

The invention will now be described by way of example, with reference to the accompanying drawings, of which:

Fig 1 shows schematically a scanning system;

Fig 2 shows schematically the effect of an orientation of a sample holder with respect to the rotatable axis;

Fig 3 shows a preferred method of scanning; and

Fig 4 is a flow diagram showing different steps according to an embodiment of the invention.

Fig 1 shows a scanning system 10 having a base 12 which supports a sample holder 14 and a back portion 16. A scanning device 18, which in this case is a probe having a scanning tip 20, is supported by the back portion 16. A sample 22 is located on the sample holder 14 for scanning. The sample holder 14 is rotatable about an axis 24 and is moveable along a vertical or Z-axis. Thus, the sample holder 14 moves along a helical path. The probe tip 20 is moveable along an axis A which is disposed at 45° to the axis of rotation 24 of the sample holder 14.

As an alternative, the sample holder 14 is rotatable and the scanning device moves in the vertical or Z direction.

Fig 2 shows the effect of a misaligned or non co-linear sample holder 14b. Instead of lying co-linearly with respect to the rotatable axis 24, as shown by dotted lines designated 14a and 22a, a misaligned sample [illegible]

when interpreting the scan data, it is assumed that the sample holder is co-linear with respect to the rotational axis 24.

To remove this source of error, either prior to or after a sample scan has occurred, the orientation of the plane of the upper surface 26b of the sample holder 14b is established.

In the simplest case, where the sample holder merely rotates, this can be achieved by taking three radially spaced apart measurements of the upper surface 26b with the probe tip (not shown). These three points define the plane of the upper surface 26b and can be used to correct data from the sample scan to reflect this real plane of the upper surface 26b.

Where the sample holder 14 is assigned a vertical movement as well as a rotational movement, more than three points are required as the helical or spiral path through which the sample holder moves will mask the actual plane of the upper surface 26b. In this situation, a number of points are taken, perhaps as individual points or, more preferably, as a single scan of the upper surface which encompasses at least two-thirds of a rotation of the sample holder. Two-thirds of a revolution is the minimum angular rotation required to define a plane accurately.

The size of the upper surface of the sample holder is a further factor which determines the size of the correctional data set. If the upper surface is small, it is preferred that a larger number of data points are taken as this then reduces the error introduced by any

surface defects.

Referring now to Fig 3, it is important that the probe tip is located accurately on the upper surface 26 so that any edge effects are not included. The sample holder 14 is provided with a chamfer 34 and the sample 22 has a rounded edge 32 where it meets the sample holder 14. If either the chamfer 34 or rounded edge 32 are scanned when the plane of the upper surface is being established (the orientation scan), errors would be introduced. Thus, in a preferred embodiment, inner and outer radial boundaries are set which define a region in which the orientation scan must occur.

The boundaries may be established by initially conducting a scan of the circumference of the sample holder 14 (the x,y boundary scan) which establishes the radius and co-ordinates of the origin of the sample holder. A known defect in the surface, for example, the chamfer 34, is subtracted from the radius of the sample holder 14 to create the outer boundary. The radius of the sample 22 plus rounded edge 32 is added to the origin of the sample holder 14 to create the inner boundary. A safety factor, for example, to account for non-central placement of the sample may also be added to or subtracted from the boundaries. The probe tip thus has a defined region 36 in which the orientation scan must occur in order to be considered viable.

encounter the sample overhang 38 instead of the upper surface of the sample holder 14. To alleviate this problem, the orientation scan may be further constricted by a z boundary which defines limits for the scan in the vertical direction. For a misaligned sample holder (see Fig 2, 14b), it is assumed that the probe tip will first encounter the upper surface 26 of the sample holder 14b at the lowest point on the plane surface as the probe scans 40 perpendicularly to the rotational axis 24. This point of first encounter is used to define z boundaries for the orientation scan. As a minimum of between two-thirds and about three-quarters (see Fig 4) of a revolution is desired to define the plane of the upper surface, the upper vertical distance is defined as a minimum of the height change experienced during one revolution. The lower vertical distance is preferably defined not as zero, but as minus about half a revolution to account for circumstances where the swash angle S is small when the assumption that the first encounter is at the lowest point may not be valid. Again additional safety factors are added to these limits.

When a z boundary has been defined, this has the effect of limiting the swash angle S that can be detected. Note, a system has a maximum swash angle with which it can function and this provides a maximum value that the z boundary cannot exceed. This can be advantageous as, the larger the swash angle S, the more eccentric the movement of the sample which can introduce additional errors into a scan. For example, when a touch probe is used, there are limits to the amount of motion the probe tip can undergo along its axis (Fig 1, axis A). When the probe nears the limits of this motion,

accuracy is reduced.

Fig 4 shows a flow diagram 100 which details the steps involved in one embodiment of determining whether or not to accept the orientation scan.

In this example, the probe conducts a single scan of the upper surface and a single revolution consists of 1820 data points being taken by the probe tip.

Firstly, the orientation scan 110 is conducted. This scan may or may not be subject to the x,y and z boundaries detailed above. Next, it is determined whether two-thirds of a revolution has been conducted 120. If not, then the orientation scan is rejected 122. If the answer is yes, then the orientation scan is accepted 124. Two-thirds of a revolution is the minimum angular range required in order that a plane can be determined accurately. In this example, two-thirds of a revolution means that 1220 data points have been collected.

In a next, optional step, the surface is divided into quadrants 130 and each quadrant is checked against a minimum number of data points 140. If any quadrant does not have the required minimum, the orientation scan is rejected 142. If all the quadrants meet this requirement, we proceed 144 to the next step. The requirement that data is collected in each quadrant provides more accuracy and consistency than the [illegible]

quadrants is statistically more accurate than the two-thirds of a revolution requirement, this is a preferred feature. In this example, a minimum data set for each quadrant is slightly less than half a whole quadrant data set i.e. 200 data points.

If this final, optional requirement is met, a best fit for the orientation of the plane is determined 150 using known mathematical techniques.

Additionally or alternatively, to ensure that any sample overhang is avoided in the calculation of the orientation of the plane of the upper surface, a maximum data set for each quadrant may be set. In this example, the number of data points per quadrant in a single revolution i.e. 455 data points is used as this limit.

If the orientation scan has been rejected, then a further scan is made which may be used instead of or as an addition to the rejected scan. Thus the orientation scan may comprise a number of discrete scans. Furthermore, the orientation scan may comprise data points from anywhere within the x,y boundary (if used) including from more than one revolution.

Although in the examples given, the scanning device used has been a touch probe, the invention is not limited to such devices and non-contact probes such as optical scanning devices are also suitable for use with the invention.

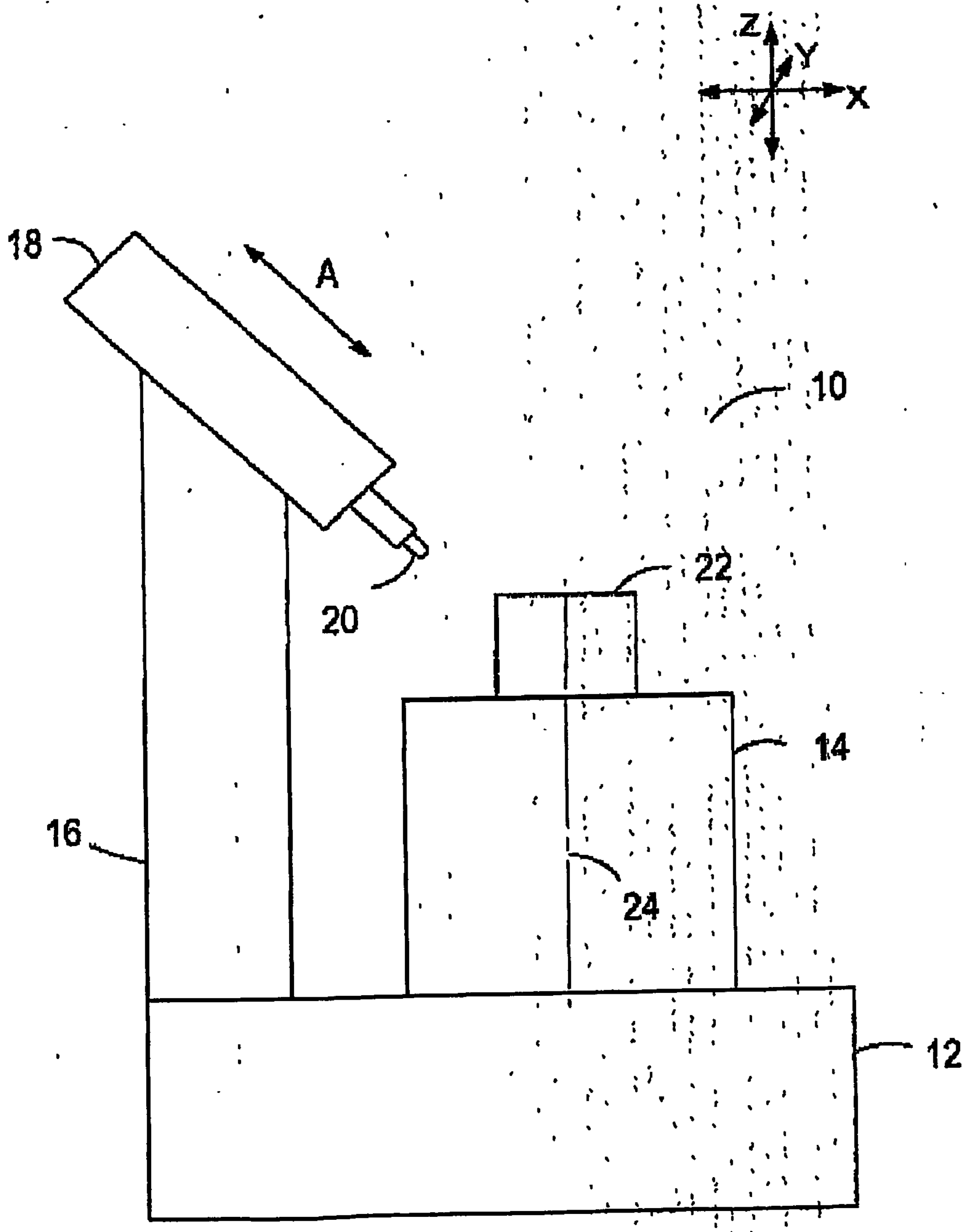

Fig. 1

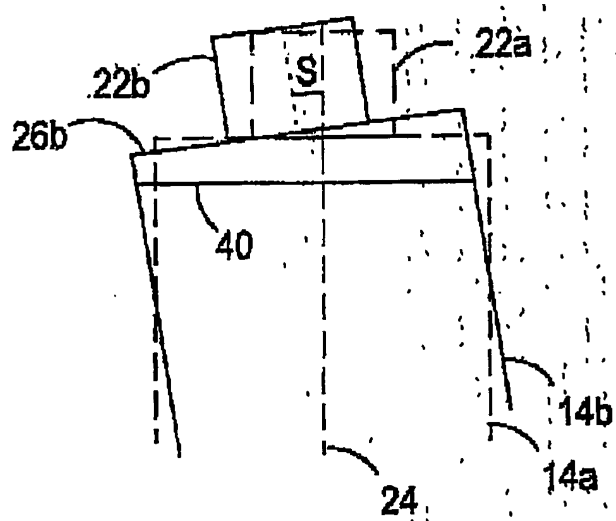

Fig. 2

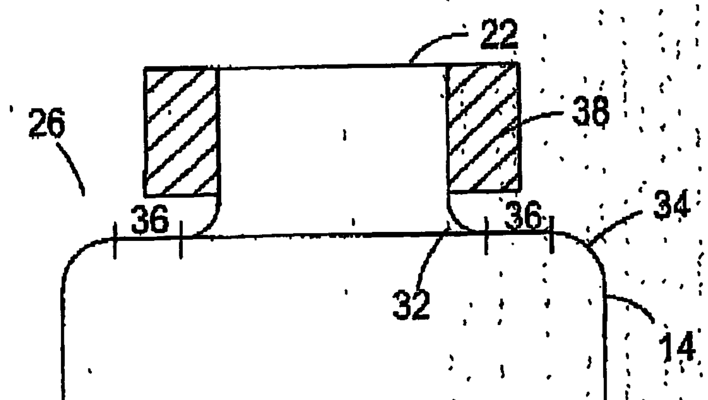

Fig. 3

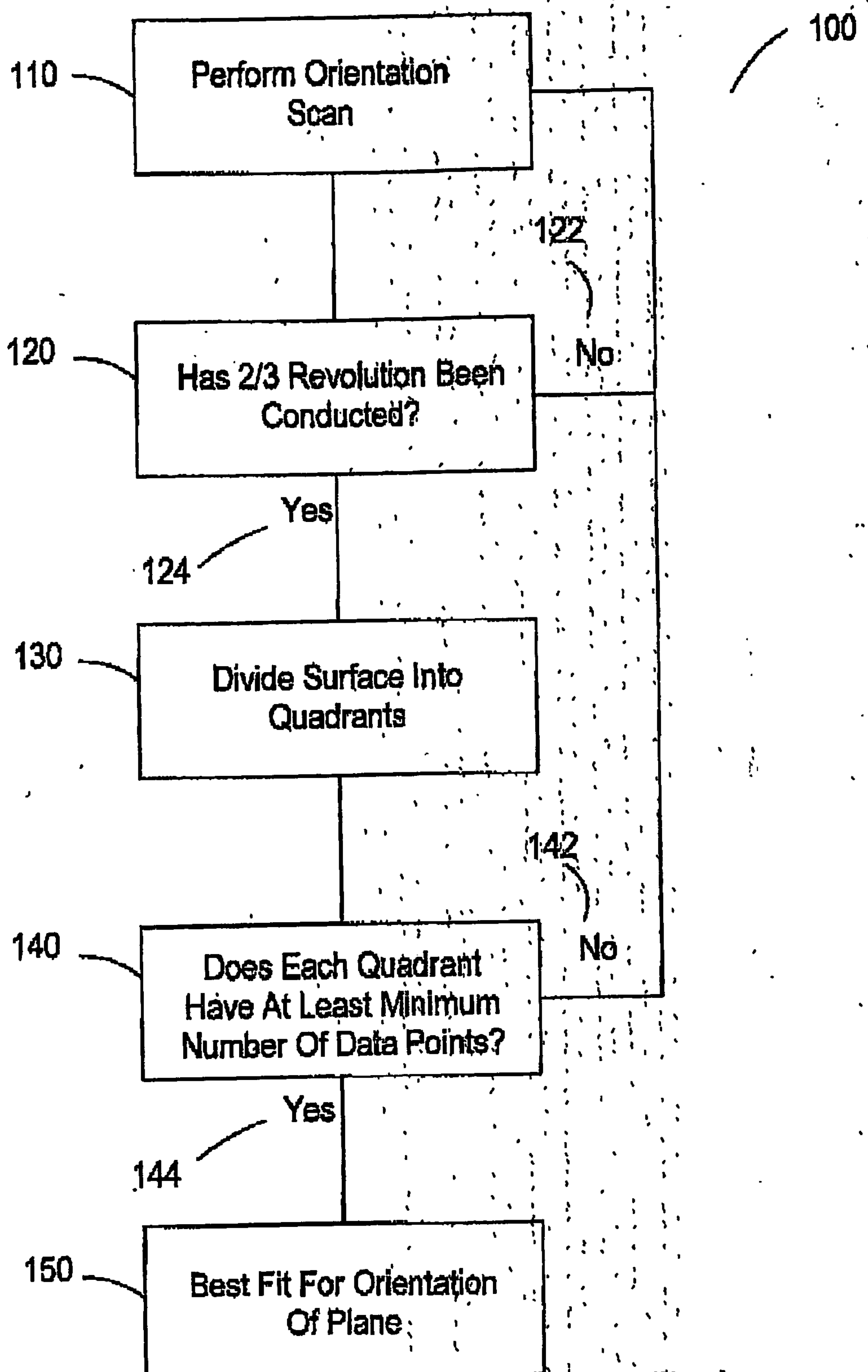
100
110
Perform Orientation Scan
120
Has 2/3 Revolution Been Conducted?
122
No
Yes
124
130
Divide Surface Into Quadrants
140
Does Each Quadrant Have At Least Minimum Number Of Data Points?
142
No
Yes
144
150
Best Fit For Orientation Of Plane

Fig. 4